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Office of the Under Secretary of Defense for Research and Engineering
Defense Research and Engineering for Research and Technology (DDRE(RT))
C5ISREW – Quantum Science Topics
22.1 Small Business Innovation Research (SBIR)
Phase I Proposal Submission Instructions

INTRODUCTION

The Office of the Undersecretary of Defense, Research and Engineering (OUSD(R&E)) Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, Reconnaissance and Electronic Warfare (C5ISREW) Office in partnership with the Director of Defense Research & Engineering for Modernization (DDRE(M)) Quantum Science Office seeks to advance scientific discoveries in alignment with the USD(R&E) Quantum Science Roadmap and provide a mechanism to further scientific development, maturation, and commercialization of quantum science technologies. The C5ISREW SBIR program aims to stimulate technological innovation, strengthen the role of small business in meeting DoD research and development needs, foster and encourage participation by minority and disadvantaged persons in technological innovation, and increase the commercial application of DoD-supported research or research and development results. **The C5ISREW SBIR program solicits approaches that combine high-risk with potential for high-reward to address scientific challenges described in the topics below.**

Proposers responding to a topic in this BAA must follow all general instructions provided in the Department of Defense (DoD) SBIR Program BAA. C5ISREW requirements in addition to or deviating from the DoD Program BAA are provided in the instructions below.

Specific questions pertaining to the administration of the C5ISREW SBIR/STTR Program and these proposal preparation instructions should be directed to: Dr. Karl Dahlhauser, karl.j.dahlhauser.civ@mail.mil.

PHASE I PROPOSAL GUIDELINES

The Defense SBIR/STTR Innovation Portal (DSIP) is the official portal for DoD SBIR/STTR proposal submission. Proposers are required to submit proposals via DSIP; proposals submitted by any other means will be disregarded. Detailed instructions regarding registration and proposal submission via DSIP are provided in the DoD SBIR/STTR Program BAA.

Technical Volume (Volume 2)

The technical volume is not to exceed 15 pages of Times New Roman size 11 font and must follow the formatting requirements provided in the DoD SBIR/STTR Program BAA. Any pages in the technical volume over 15 pages will not be considered in proposal evaluations.

Cost Volume (Volume 3)

Phase I projects may have a period of performance up to 12 months and a funding level up to $250,000. Costs must be clearly identified on the Proposal Cover Sheet (Volume 1) and in Volume 3.

Company Commercialization Report (CCR) (Volume 4)

Completion of the CCR as Volume 4 of the proposal submission in DSIP is required. Please refer to the DoD SBIR/STTR Program BAA for full details on this requirement. Information contained in the CCR will be considered by C5ISREW during proposal evaluations.

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Supporting Documents (Volume 5)
Supporting documents will be accepted/required as indicated in each topic.

PHASE II PROPOSAL GUIDELINES
Phase II proposals may only be submitted by Phase I awardees. Phase II projects may have a period of performance up to 36 months, including option years, and a funding level up to $1,700,000.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)
The DDRE(RT) C5ISREW Office will not participate in the Technical and Business Assistance.

EVALUATION AND SELECTION
All proposals will be evaluated in accordance with the evaluation criteria listed in the DoD SBIR/STTR Program BAA.

Proposing firms will be notified of selection or non-selection status for a Phase I award within 90 days of the closing date of the BAA.

Refer to the DoD SBIR/STTR Program BAA for procedures to protest the Announcement.
As further prescribed in FAR 33.106(b), FAR 52.233-3, Protests after Award should be submitted to: Dr. Karl Dahlhauser, karl.j.dahlhauser.civ@mail.mil.

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C5ISREW SBIR 22.1 Phase I Topic Index

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OSD221-006 TITLE: Stand-alone multi-axis compact portable quantum accelerometer

OUSD (R&E) MODERNIZATION PRIORITY: Quantum Science

TECHNOLOGY AREA(S): Sensors, Electronics and Electronic Warfare

OBJECTIVE: Build a compact portable 3-axis quantum-based accelerometer and demonstrate on a moving platform.

DESCRIPTION: A significant portion of quantum IMU development has focused on single-axis inertial sensors. Of these, the majority have been gyroscopes and gravimeters instead of full-scale accelerometers. Although some approaches measure both rotation and acceleration simultaneously, the resulting measurements are of limited use to practical systems. The DoD seeks the development of a stand-alone multi-axis quantum accelerometer that can simultaneously offer competitive sensitivity, bandwidth, full-scale range, bias error, and scale factor performance as compared to conventional accelerometers. A realistic pathway must be established towards a portable version that can be flown on an aerial vehicle in a GPS-denied environment. The accelerometer can be purely quantum or a hybrid combination of classical and quantum sensors. The pathway to demonstration will be required, and development of optical and electronic systems must have a clear and direct purpose towards meeting that goal.

PHASE I: Demonstration of a compact 3-axis quantum-based accelerometer on a moving platform that promises pathway towards miniaturization which will be undertaken in Phase II.

PHASE II: Demonstration of a 3-axis quantum-based accelerometer on a DoD-provided aerial platform with the following minimum characteristics:

- Full Acceleration Vector Output Rate >100 Hz
- White Noise $<1\times 10^{-5}$ g/√Hz
- Bias Stability $<5\times 10^{-6}$ g
- Scale Factor Stability <10 ppm
- Full-Scale Range >±10 g
- Volume (including all electronics and optical systems) $<0.3\ m^3$

PHASE III DUAL USE APPLICATIONS: Military applications for a 3-axis quantum-based accelerometer include inertial navigation of ships, spacecraft, aircraft, and undersea/underground vehicles that operate in GPS-degraded environments. Further commercial applications include gravity mapping, natural resource exploration, earthquake monitoring, and detection of underground tunnels.

REFERENCES:

1. P Cheiney, et al., Navigation-Compatible Hybrid Quantum Accelerometer Using a Kalman Filter. Phys. Rev. Applied 10, 034030. 17 September 2018. Phys. Rev. Applied 10, 034030 (2018) - Navigation-Compatible Hybrid Quantum Accelerometer Using a Kalman Filter (aps.org).
2. X Wu, et al., Multiaxis atom interferometry with a single-diode laser and a pyramidal magneto-optical trap. Optica 4, 12. 20 December 2017. OSA | Multiaxis atom interferometry with a single-diode laser and a pyramidal magneto-optical trap (osapublishing.org).
3. X Wang, et al., Enhancing Inertial Navigation Performance via Fusion of Classical and Quantum Accelerometers. ArXiv 2103.09378. 17 March 2021. [2103.09378] Enhancing Inertial Navigation Performance via Fusion of Classical and Quantum Accelerometers (arxiv.org).
4. B Barrett, et al. Inertial quantum sensors using light and matter. Physica Scripta 91, 5. 13 April 2016. Inertial quantum sensors using light and matter – IOPscience.

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5. R Geiger, et al., Detecting inertial effects with airborne matter-wave interferometry. Nature Communications 2, 474. 20 September 2011. Detecting inertial effects with airborne matter-wave interferometry | Nature Communications.

KEYWORDS: Quantum; Accelerometer; Inertial Navigation; Atom; Sensor

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OSD221-007 TITLE: High yield atomic vapor cell manufacturing and packaging for atomic clocks and magnetometers

OUSD (R&E) MODERNIZATION PRIORITY: Quantum Science

TECHNOLOGY AREA(S): Sensors, Electronics and Electronic Warfare; Materials / Processes

OBJECTIVE: Develop a manufacturing process which allows greater yield (>80%) per wafer batch on vapor cell wafer runs to support quantum clocks and magnetometers.

DESCRIPTION: Over the last decade, quantum sensor technology (including atomic clocks and atomic magnetometers) have accelerated in performance to provide new and important capabilities for the DoD. While the performance of these quantum devices has improved significantly, the ability to deploy them for DoD missions is still lacking due to inadequate processing and manufacturing capabilities, specifically at capacities needed to meet the SWaP-C requirements for DoD deployable systems. One area of improvement lies at the heart of these quantum devices - the atomic vapor cell. Even with commercialized atomic clocks and magnetometers, manufacturing techniques to fabricate vapor cells and thermal packages have proved elusive, often resulting in low yield and considerable added expense to the device. The fabrication of these vapor cells typically requires high heat and high voltage in a process called anodic bonding which complicates the manufacturing process and leads to inconsistency in the final product. We are seeking a microfabrication technique for parallel, batch manufacturing of vapor cells that does not rely on anodic bonding for the final seal. The technology should be capable of scaling to high volumes with production yields that exceed 80 percent and a path towards producing hundreds of thousands of vapor cells per year. Proposing companies should also include compact packaging techniques that provide thermal stability and power reduction. These advances will allow for quantum devices to be produced at significantly lower cost, with the goal to achieve significantly wider dissemination across the DoD. We are looking for vapor cell manufacturing and packaging technologies that accelerate manufacturing, produce greater quantity per batch, provide reduced part-to-part variation (greater consistency), improve SWAP (size, weight, and power), and provide overall cost reductions for quantum sensors like atomic clocks and atomic magnetometers.

PHASE I: A successful Phase I will demonstrate the production of vapor cells with yield greater than 70 percent on a substrate having a cavity array of 5x5 and using a non-anodic bonding technique. The cells must demonstrate a judicious proportion of alkali gas, buffer gas, and leak proof vapor cell manufacturing. A design for packaging the cells should also be included.

PHASE II: Phase II will advance the phase I techniques to successfully demonstrate manufacturing runs on a full wafer-scale substrate while achieving a production yield that exceeds 80 percent. The packaging solution should be demonstrated in a prototype device. A sample of vapor cells should be substantiated by using them to demonstrate either an atomic clock or an atomic magnetometer.

PHASE III DUAL USE APPLICATIONS: Commercial applications include smaller, more affordable atomic clocks for use in navigation and enhanced cellular timing holdover, and magnetometers for geological surveying and mineral prospecting. DoD applications involving magnetometers like magnetic anomaly detection can benefit from inexpensive sensors that are low enough powered to fly on small UAS.

REFERENCES:

1. S. Knappe, V. Gerginov, P. D.D. Schwindt, V. Shah, H. G. Robinson, L. Hollberg, and J. Kitching, "Atomic vapor cells for chip-scale atomic clocks with improved long-term frequency stability," Opt. Lett. 30, 2351-2353 (2005).

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2. Yanjun Zhang, Yunchao Li, Xuwen Hu, Lu Zhang, Zhaojun Liu, Kaifang Zhang, Shihao Mou, Shougang Zhang, and Shubin Yan, "Micro-fabrication process of vapor cells for chip-scale atomic clocks," Chin. Opt. Lett. 17, 040202- (2019).
3. John Kitching , "Chip-scale atomic devices", Applied Physics Reviews 5, 031302 (2018) https://doi.org/10.1063/1.5026238.

KEYWORDS: Vapor Cell Manufacturing; Atomic Clocks; Atomic Magnetometer; high Yield

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